

# Electroweak penguins in isospin-violating $B_s$ decays

Lars Hofer<sup>ab</sup>, Dominik Scherer<sup>\*,a</sup> and Leonardo Vernazza<sup>c,†</sup>

<sup>a</sup> *Institut für Theoretische Teilchenphysik,  
Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany*

<sup>b</sup> *Institut für Theoretische Physik und Astrophysik,  
Universität Würzburg, D-97074 Würzburg, Germany*

<sup>c</sup> *Institut für Physik (THEP),  
Johannes Gutenberg-Universität, D-55099 Mainz, Germany  
E-mail: lars.hofer@physik.uni-wuerzburg.de,  
dominik@particle.uni-karlsruhe.de, vernazza@uni-mainz.de*

The  $2.5\sigma$  discrepancy between theory and experiment observed in the difference  $\Delta A_{\text{CP}} = A_{\text{CP}}(B^- \rightarrow \pi^0 K^-) - A_{\text{CP}}(\bar{B}^0 \rightarrow \pi^+ K^-)$  can be explained by a new electroweak (EW) penguin amplitude. Motivated by this result, we have analyzed the purely isospin-violating decays  $\bar{B}_s \rightarrow \phi \pi^0$  and  $\bar{B}_s \rightarrow \phi \rho^0$ , which are dominated by EW penguins. Our results extend the analysis in [1] and have recently been published in [2]. Here we give a brief overview of the outcome.

We show that in presence of a new EW penguin amplitude the two  $B_s$  branching ratios can be enhanced by an order of magnitude without violating any constraints from other hadronic  $B$  decays. This makes them very interesting modes for LHCb and Super  $B$  factories. We perform both a model-independent analysis and a study within realistic New Physics (NP) models such as a modified- $Z^0$ -penguin scenario, a model with an additional  $Z'$  boson and the MSSM, including a fit to  $B \rightarrow \pi K$  data and the relevant experimental constraints throughout. In the model-independent case we study effective  $b \rightarrow s\bar{q}q$  couplings and distinguish between several possible chirality structures. Constraints arise from a large number of hadronic  $B$  decays such as  $B \rightarrow \pi K^{(*)}, \rho K^{(*)}, \phi K^{(*)}$  etc. The preferred fit regions are rather large and allow for order-of-magnitude enhancements (see plots). In concrete models the new amplitude can often be correlated with other flavour phenomena, such as semileptonic  $B$  decays and  $B_s$ - $\bar{B}_s$  mixing, which set stringent constraints on the enhancement of the two  $B_s$  decays. In particular we find that, contrary to claims in the literature, EW penguins in the MSSM can reduce the discrepancy in  $\Delta A_{\text{CP}}$  only marginally. Consequently no visible enhancement of  $\bar{B}_s \rightarrow \phi \pi^0, \phi \rho^0$  is expected for this model. As byproducts of our work we update the Standard Model (SM) predictions to  $BR(\bar{B}_s \rightarrow \phi \pi^0) = 1.6^{+1.1}_{-0.3} \cdot 10^{-7}$  and  $BR(\bar{B}_s \rightarrow \phi \rho^0) = 4.4^{+2.7}_{-0.7} \cdot 10^{-7}$  and perform a state-of-the-art analysis of  $B \rightarrow \pi K$  amplitudes in QCD factorisation (QCDF).

*35th International Conference of High Energy Physics  
July 22-28, 2010  
Paris, France*

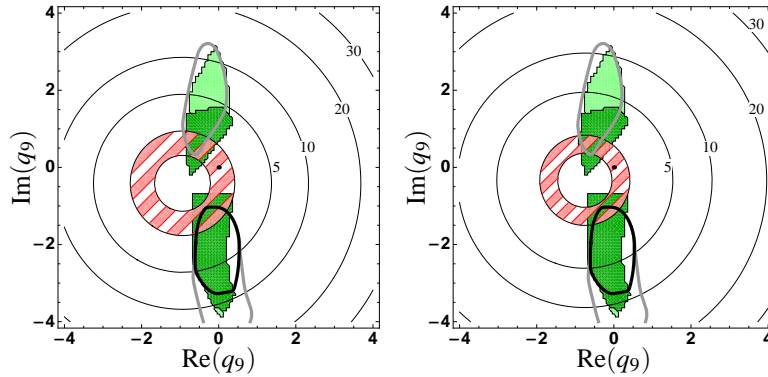
\*Speaker.

<sup>†</sup>TTP10-51, MZ-TH/10-46, SFB/CP-10-129. Supported by Deutsche Forschungsgemeinschaft SFB/TR9, BMBF contract 05H09WWE, Cusanuswerk, Studienwerk Villigst and Alexander-von-Humboldt foundation

**Amplitude structure of  $\bar{B}_s \rightarrow \phi \pi^0$  and  $\bar{B}_s \rightarrow \phi \rho^0$ :** The two decay modes discussed here are *pure*  $\Delta I = 1$  transitions, which means that there are no QCD penguin contributions at all. Calculating both amplitudes in QCDF the dominant SM contribution comes from a  $Z^0$  penguin with pollution from a CKM- and colour-suppressed tree amplitude and possibly from OZI-suppressed singlet annihilation. We provide convenient approximate expressions for the amplitudes in [2].

**Effects of new EW penguin amplitudes:** We study the effects of new EW penguin amplitudes in different ways:

- a) We parameterise the new amplitudes in a model-independent way via complex numbers  $q_i$ . Here we show the enhancement factors (circles) of  $BR(\bar{B}_s \rightarrow \phi \pi^0)$  (left) and  $BR(\bar{B}_s \rightarrow \phi \rho^0)$  (right) w.r.t. the SM as a function of  $q_9$ , corresponding to an EW  $b_L \rightarrow s_L \bar{q}_L q_L$  penguin. For  $|q_9| = 1$  the corresponding SM penguin receives a 100% correction. Dark green areas are allowed by constraints from hadronic  $B$  decays while the solid black lines mark the preferred ( $1\sigma$ ) region of the  $B \rightarrow \pi K$  fit. Lighter areas and lines only take into account observables particularly sensitive to isospin-violation. The hatched rings mark the theoretical uncertainty of the SM branching ratios. We see that an order-of-magnitude enhancement is possible for both branching ratios. The same is true for several right-handed and mixed NP amplitudes.



- b) We calculate the new amplitudes in concrete NP models. We find that flavour-changing  $Z$ -couplings cannot produce large effects because of tight constraints from semileptonic  $B$  decays. These constraints can be relaxed in  $Z'$  models since the  $Z'$  couplings to leptons are unknown. The most important constraint in this model comes from  $B_s - \bar{B}_s$  mixing, it allows for enhancements of up to a factor of  $\sim 5$  in the  $B_s$  decays. In the MSSM we find that no large isospin-violating effects are possible at all, neither in  $\Delta A_{CP}$  nor in the two  $B_s$  decays.

**Conclusion:** We strongly encourage experimental efforts towards a measurement of  $\bar{B}_s \rightarrow \phi \pi^0$  and  $\bar{B}_s \rightarrow \phi \rho^0$  at LHCb and Super  $B$  factories.

## References

- [1] L. Hofer, D. Scherer, L. Vernazza, *Search for New Physics in Electroweak Penguins via  $B_s$  Decays*, *Acta Phys. Polon.* **B3** (2010) 227-233.
- [2] L. Hofer, D. Scherer, L. Vernazza,  *$\bar{B}_s \rightarrow \phi \pi^0$  and  $\bar{B}_s \rightarrow \phi \rho^0$  as a handle on isospin-violating New Physics*, arxiv:1011.6319.